BELLCOMM, INC.
1100 Seventeenth Street, N.W. Washington, D.C. 20036

SUBJECT: Launch Vehicle Digital Computer (LVDC) Requirements for the Apollo Applications Program Case 600-2

DATE: June 20, 1967

FROM: J. J. Rocchio

MEMORANDUM FOR FILE

Introduction

The initial series of AAP missions are currently being defined. The purpose of this memorandum is to assess the impact of this mission planning on the Saturn IB/V Launch Vehicle Digital Computer (LVDC), which with its associated input/output unit, the Launch Vehicle Data Adapter (LVDA) is the main computational element of the Saturn Guidance System. In addition to considering early AAP missions, it is appropriate to consider at this time the potential impact of future, less well-defined AAP missions on the LVDC, particularly as parallel efforts are being extended* to explore means of increasing its memory capacity.

Functional Requirements of the Saturn Guidance & Navigation (G&N) System

The LVDC and LVDA are housed in the Instrument Unit (IU) stage of the Saturn launch vehicles. This stage is mounted on top of the S-IVB stage. The IU is required to provide the following principal functions:

(1) Space vehicle navigation and guidance, and launch vehicle flight event sequencing

(2) Space vehicle attitude control.

(3) Instrumentation (flight data acquisition).

(4) Ground radar tracking augmentation.

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*An initial (phase I) study of means of providing an auxiliary memory unit (AMU) for the LVDC was conducted by IBM during June - September 1966;(1) currently, a phase II study effort is underway concentrating on a core-tape AMU configuration.

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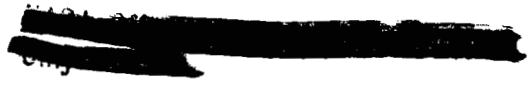
ABSTRACT

The most probable impact of the early AAP missions on the Launch Vehicle Digital Computer (LVDC) will be in flight program growth, although at present no major new requirements are known. Thus, the current Saturn I LVDC configuration of six memory modules may be sufficient with expansion to eight modules (32k 28-bit words) possible.

Explicit LVDC requirements for AAP missions beyond the initial series are not available and there is no indication that program growth beyond the maximum LVDC capacity will occur. Basically, the function and role of the LVDC is tied to the Saturn Instrument Unit (IU) which provides it with power and coolant. Upgrading the IU by extending its life, for example, could require additional computational support for added IU systems (e.g., attitude control) or payload (e.g., experiments). AAP requirements for the LVDC then, should be considered as integrally dependent on the role of the IU in advanced AAP missions.



(5) Ground command reception.

(6) Emergency detection system stimuli reception, processing and issuance.

(7) Electrical power for IU subsystems.

(8) Environmental control for the IU and forward skirt of the S-IVB stage.

(9) Structural support suitable for the above functions and vehicle-to-spacecraft load transfer.

The Environmental Control System (ECS) of the IU provides both coolant and power to the LVDC/LVDA among other IU subsystems. In addition, the ECS provides nitrogen for the gas-bearing gyroscopes and accelerometers of the stable platform (ST-124M). Both the gas supply and thermal control systems in the current IU operate open cycle with nominal lifetimes of 13.2 hours and 13.8 hours at 3.25 kw power dissipation, respectively. Taking the AS-205 IU (3-battery system) as a baseline for the uprated Saturn I launch vehicle, the power supply is the constraining item on IU lifetime with a capacity of 10 hours at 2.5 kw dissipation. Power is also the constraining item for the Saturn V; with AS-504 (4-battery system) as a baseline, IU lifetime is 11.25 hours at 2.5 kw dissipation. A 5-battery configuration would provide an IU capable of supporting a 12-hour mission with only minor ECS modifications.[2]

The computer subsystem accomplishes its major guidance system functions through execution of the guidance portion of the flight program. The LVDC software contains both preflight and flight routines. Flight programs may be divided into four major parts:

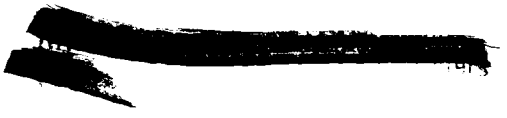
(1) Major loop

(2) Minor loop

(3) Interrupts and flight sequencing operations

(4) Telemetry processing

The major loop contains the guidance program made up of navigation, steering calculations, and timekeeping. Accelerometer processing and control system computations are performed



in the minor loop. The other two program divisions handle the LVDC's interface with other IU subsystems.

The maximum memory capacity of the LVDC is 8 modules of 4,096 28-bit words. This capacity provides 16k duplexed storage words which may be divided between 28-bit data words and 13-bit instruction words. Present procurement allocates 6 modules to AS-200 series flights and 8 modules to AS-500 series flights. The increased memory required for the Saturn V launch vehicle arises due to increased mission capability (e.g., variable launch azimuth, ground guidance update, and increased abort-to-orbit capability), and to the additional sequencing and guidance functions associated with the additional S-II stage.

At this time, spare capacity in the LVDC memory for AS-206 is on the order of 4 sectors and for AS-504, 7 sectors (duplex in each case). A 4k memory module contains 16 sectors of 256 words each. Recent study of program organization indicates that additional memory space can be made available by program reorganization.(3) For example, it is reasonable to expect on the order of one spare duplex module (4k) for the AS-504 mission.(4)

AAP Requirements - Initial Missions

The initial series of AAP missions all involve an uprated Saturn I launch vehicle in low altitude (100-300 nm) earth-orbital missions. The major distinguishing features of these missions from Apollo 200-series missions (with respect to the launch vehicle) are:

(1) Conversion of an S-IVB stage to an orbital workshop; and

(2) CM rendezvous and docking with the unmanned payload and S-IVB stage on the prime Orbital Workshop and Solar Astronomy missions (AAP-1 and AAP-3) and on the revisit missions (AAP-3A and AAP-5).

LVDC support requirements for these missions with respect to the primary G&N functions can be expected to be similar to AS-200 series flights. For the Orbital Workshop, some mission peculiar requirements for S-IVB passivation are known. (The LVDC controls a series of actions which dump unused LH_2 and LOX and vent various tanks and gas supply reservoirs.) These can be implemented with minor LVDC

program additions to switch selector operations. At the present stage of planning, the IU lifetime is a constraining item on AAP rendezvous missions. Means of providing additional attitude stabilization of the S-IVB is under study including, for example, the possible use of an open loop control moment gyro system in the orbital workshop. No LVDC requirements for increased attitude stabilization are currently known; further, as the LVDC is dependent on the ECS of the IU, it will be unusable once the IU runs out of expendables (10-12 hours after liftoff).

At this stage of mission planning for initial AAP flights, no major new LVDC requirements are known. The most likely impact will be in program growth arising for example from mission flexibility requirements. As the LVDC can accommodate two additional memory modules over the six currently allocated for the Saturn I, this should provide a more than adequate reserve. Since, however, memory module procurement could have a schedule impact, it is suggested the LVDC program requirements be updated as soon as mission planning allows meaningful memory estimates to be made. In this connection it should be noted that about one year is normally required just to develop and verify LVDC software for an Apollo mission. This lead time can be assumed for AAP missions only if there is no conflict with Apollo in the use of the required software development facilities.

AAP Requirements - Missions Beyond the Initial Series

At this point, future AAP missions can only be discussed in a speculative sense. In addition to Saturn V lunar missions both Saturn I and Saturn V earth-orbital missions are being contemplated. The major impact of AAP lunar missions will be on CM and LM systems rather than on the launch vehicle. At this stage of program definition no major impact on LVDC requirements is foreseen. Future AAP earth-orbital operations have been studied in greater detail. The achievement of a polar or synchronous orbit for example requires a yaw excursion greater than the maximum allowed ($\pm$ 45° during powered flight) by the middle platform gimbal of the IU stable platform. The yaw excursion required arises out of operational constraints governing the relation of ascent flight to land masses. Study of this problem has indicated that a LVDC program using a "yaw biasing" technique can circumvent this restriction with no changes to the existing IU.(2)

In general, LVDC requirements for AAP earth-orbital operations can be considered in two phases. The primary requirement of the LVDC arises in ascent to orbit and during orbital burn. During these periods, guidance and navigation computations use a large percentage of LVDC's computational

capacity. LVDC requirements during these phases of AAP missions can be expected to differ only slightly from the corresponding Apollo mission phases. During orbital coast, however, the guidance and navigation computational load on the LVDC is small, and it serves other IU systems by performing telemetry data compression for example. With the current IU design, LVDC lifetime in orbit will be comparable to what is expected for Apollo and it is not likely that any significantly different functional requirements will develop.

However, if the IU life is extended, it then becomes likely that new functional responsibilities will evolve for the LVDC in the areas of computational support of added IU subsystems or payloads. The use of an extended life IU to support earth-orbital experiments has already been studied (see reference 2). In this application the LVDC can provide a wide range of support functions depending on the IU and payload configuration. These range from relatively simple experiment control/sequencing functions (as, for example, when the IU is attached to a manned CM) to more complex stabilization and data processing functions which might be required in connection with an orbital workshop mission. Memory requirements for the LVDC in these roles will vary correspondingly--the former possibly within the capacity of the current LVDC, the latter requiring additional memory space. In such applications, it should be noted that an astronaut-LVDC interface will be required and this may necessitate some LVDC modifications. Currently, the LVDC is accessible only via the telemetry uplink.

It thus appears likely that any major new functional requirements for the LVDC arising out of the AAP program will result from decisions to upgrade the total IU system, and therefore should be studied in this respect. Thus, an upgraded IU may or may not require computational support beyond the capacity of the present LVDC depending on the functional use made of the IU. Assuming additional support is required, an LVDC with auxiliary memory may be sufficient, or may either not be cost effective or not capable of providing such support. In the latter cases, other alternatives, e.g., major LVDC redesign or the use of a new computer, would have to be considered. However, it appears unlikely that any increase in LVDC capabilities, as would be gained by the addition of auxiliary memory, for example, will be required given the current IU lifetime. Moreover, any AAP applications which warrant a decision to extend the operational life of the Saturn IU will require a sufficient lead time (for IU modifications) to allow parallel development of an AMU for the LVDC. Thus, LVDC memory capacity can not be considered to be constraining for such applications.

Summary

At this stage of program definition, no major increase in LVDC requirements over Apollo are foreseen arising out of the early AAP missions. This conclusion also applies on a tentative basis to AAP missions beyond the initial series, with the exception noted that increased functional responsibility for the Saturn IU (available if IU life is extended) may also place new requirements on the LVDC.

J. J. Rocchio

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Attachment
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